INSTITUTE OF PAPER CHEMISTRY
Appleton · Wisconsin

COMPARATIVE EVALUATION OF WHOLE TREE AND CONVENTIONAL KRAFT PULPS

FKI Project 2926-4
IPC Project 3133

Report Two

A Progress Report

to

TECHNICAL DIVISION
FOURDRINIER KRAFT BOARD INSTITUTE, INC.

May 7, 1974

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TABLE OF CONTENTS

	Page
SUMMARY	1
INTRODUCTION	2
DESIGN OF EXPERIMENT	3
DISCUSSION OF RESULTS	5
Commercial Pulps	5
Laboratory Pulping	5
CONCLUSIONS	25
EXPERIMENTAL	28
ACKNOWLEDGMENTS	32
LITERATURE CITED	33

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COMPARATIVE EVALUATION OF WHOLE TREE AND CONVENTIONAL KRAFT PULPS

SUMMARY

Means for improving fiber yield from American woodlands were investigated. The subject of this report is a comparison of laboratory-prepared kraft pulps made from (a) debarked pinewood and (b) chips made from whole pine trees (less stump).

It was found that there was about 10% of extraneous material in the whole tree chips provided by Hoerner Waldorf Corp., Roanoke Rapids, N.C. and that most of this was removed by pulping. Reaction of cooking chemical with these nonwood constituents resulted in reduced delignification of the wood fraction, with consequent lower yield of a higher lignin content pulp. Standard beater evaluations provided evidence that the pulp made from whole trees was somewhat deficient in tearing strength as compared with the control pulp but was not otherwise inferior. No clearcut indications were found that the use of whole tree chips would increase such production problems as excessive depositable pitch or foaming. When beaten and combined with the beaten control pulp from debarked wood, and made into board weight handsheets, up to 50% whole tree pulp did not change the usual sheet strength properties with the single exception of tearing strength which was minimally lower at the highest dilutions with whole tree pulp.

Comparisons were also made with a sample of commercial linerboard pulp made from debarked wood but these were not particularly useful since the laboratory-prepared pulps were appreciably stronger.

INTRODUCTION

The work described in this report was initiated as a result of industry concern with the long-range necessity for conserving wood resources. One obvious way is to operate woodlands in such a fashion as to produce the greatest amount of product possible from each tree. Another is to increase the yield of pulp from the raw material received from the grower. A literature survey (1) was made which covered both of these possibilities. It demonstrated that much more work had been reported on yield enhancement than on the effect of pulping more of the tree. Since the survey was completed, several papers on the latter subject have been published, reflecting the increased awareness in the industry of the potential of this wood conservation measure.

The whole tree pulping experiments performed at the Institute were made possible by the availability of raw material from a commercial operation of whole tree chippers harvesting pinewood.

DESIGN OF EXPERIMENT

It was originally proposed that a literature search covering high-yield kraft pulping of barked and unbarked wood precede laboratory evaluation of whole pine tree kraft pulp obtained from the Albemarle Paper Company mill at Roanoke Rapids, North Carolina. Control tests on a "typical" high-yield pine kraft would be made simultaneously. The literature survey (1) was authorized on September 29, 1972 and the results were reported on December 27, 1972. Reconsideration of the inherent difficulties of relating two basically different wood pulps resulted in the decision to compare pulps made in the laboratory from two chip samples. Arrangements were made to obtain chips made from debarked pine roundwood and another sample derived from whole pine trees, both from the Albemarle Paper Company mill at Roanoke Rapids, North Carolina (a subsidiary of Hoerner Waldorf Corporation). The "whole tree" chips were described as being inclusive of all bark, limbs, twigs, needles, etc., as well as the unbarked tree trunk, but exclusive of the stump. The kraft pulping conditions used to produce a conventional pine kraft pulp of 60 Kappa number were supplied with the chips, as were samples of mill pulps taken from various points in the system.

Tests specified for the raw materials included an inspection of the whole tree chips to provide information on the amount of nonwood material present.

Pulping of the two woods by identical methods was expected to supply data on ease of delignification, yield, and pulp properties. Among the latter, in addition to the usual strength measurements were included extractives, level of depositable pitch, calcium content, and any observations concerning evidences of different levels of foaming or stickiness of the fiber slurries. Pulp strength properties were measured directly by the preparation of 60 g/m^2 handsheets from both types of pulp over a range of refining times in the 1 1/2-lb Valley beater. In addition, mixtures of the two pulps were formed into handsheets at heavier basis weights such as those represented by board weights of 26 and 42 lb/1000 ft^2.

Other tests applied were fiber length distributions as measured by fiber classification, inspection of photomicrographs of representative samples for evidence of morphological differences and examination of ash contents. It was suggested that the beaten fibers of both kinds of pulp be examined for filtration resistance. The latter was not done because of reservations concerning the sensitivity of the test method at the refining levels of interest to the cooperating companies.

DISCUSSION OF RESULTS

COMMERCIAL PULPS

The design of the experiment did not call for a comparison of the laboratory-prepared pulp with a typical commercial high-yield kraft softwood pulp but samples were obtained from the Roanoke Rapids mill for use as references for refining levels. Fiber classification of samples taken before and after the mill refiner and one taken from the machine headbox were performed according to TAPPI Method T 233 su-64. The data appear in Table I. Since the pulps were available, handsheets were made from the headbox stock and from the post-refiner stock after several beating intervals in a 1 1/2-lb Valley beater (Methods T 200 ts-66 and T 205 m-58). These were tested for density, burst, tear, and tensile strength. Data taken, including freeness drop in beater processing, are given in Table II.

LABORATORY PULPING

The chip samples were well mixed and packaged as described elsewhere (under Experimental). Part of the whole tree chip sample was reduced to about 400 g green weight by quartering. This material was manually separated into four constituents. On a moisture-free basis, these were:

Wood free of bark, %	88.4
Wood with residual bark, %	4.5
Bark, %	6.6
Twigs and needles, %	0.5

TABLE I

FIBER CLASSIFICATION DATA

(Average of duplicate tests)

Pulp	Commercial			Experimental	
	C-Washer	Refiner	Headbox[a]	Cook 4[b]	Cook 5[c]
On 12 M, %	38.3	41.2	35.6	65.9	75.0
Through 12 M, on 20 M, %	24.8	23.4	18.5	9.0	5.2
Through 20 M, on 48 M, %	23.8	22.6	25.7	16.7	11.6
Through 48 M, on 100 M, %	5.4	5.2	8.2	2.8	2.0
Through 100 M, by difference, %	7.7	7.6	12.0	5.6	6.2

[a] Contains some hardwood fiber.
[b] Pulp made from whole tree chips.
[c] Pulp made from debarked pine chips.

TABLE II

PHYSICAL PROPERTIES OF COMMERCIAL PULPS

Beating interval, min	0	5	15	30	50	Headbox
Canadian Standard Freeness, ml	750	735	690	590	330	650
Basis weight, g/m^2	59.8	60.2	61.4	61.1	61.4	60.4
Density, g/cc	0.426	0.467	0.531	0.588	0.62	0.518
Burst factor	25.6	37.1	49.1	56.1	60.9	37.6
Tear factor	193	175	152	134	113	143
Tensile, br. length, km	4.49	5.52	7.13	8.18	8.77	5.88

It is estimated that one half of the weight of the chips with firmly adhering bark was wood. Given this assumption, it can be calculated that there was about 90.6% as much wood in the raw material from whole tree chipping going to the digester as was the case in a cook involving debarked wood. If the lignin content of the wood is assumed to be 28% (2) (and none in the bark and needles), the equivalent amounts of lignin and nonlignin in the two cooks would be:

Cook 4 — Whole tree — 25.4 lignin — 74.6 nonlignin

Cook 5 — Barked pine — 28 lignin — 72 nonlignin.

The reason that the mill conditions (shown in Table III, Cook 1) did not produce a pulp from the pine chips in the 60 Kappa number range quite likely has to do with factors such as the use of water as a chemical diluent in the laboratory experiment instead of spent liquor containing residual alkali as done in the mill, hydrostatic head pressures found in the mill and others. The easiest variable to change in the laboratory, however, was time at maximum temperature. It required three cooks to attain the target Kappa number level and Cook 4 was made with the whole tree chips with the same time at maximum temperature calculated to be necessary for pulping the pine chips to 60 Kappa number. Table III reveals that identical pulping conditions applied to conventional pine chips and whole tree chips gave different products. The lignin content of the 51.7% yield pulp from the debarked wood (Cook 5) was found to be 11.7% while that of the whole tree pulp (47.5% yield) was 14.8%. While it has recently been postulated (3) that bark present in a kraft digester does not consume as much of the chemical as had been previously thought, this single experiment indicates that the nonwood portion of the raw material must have had a substantial impact on the cooking process. Going back to the figures cited

TABLE III

PULPING CONDITIONS AND PRODUCT VARIABLES
HIGH YIELD KRAFT PULPING STUDY

Cook	1	2	3	4	5
Wood sample	A	A	A	B	A
Digester charge, kg a.d.	8.995	8.998	9.000	9.491	8.997
Digester charge, kg o.d.	4.392	4.392	4.392	4.578	4.392
Time at max. temp., min	40	60	68	65	65
Kappa no.	82.8	67.2	55.7	76.0	60.5
Total lignin, %	--	--	--	14.8	11.7
Yield, %	61.5	52.6	50.3	47.5	51.7

Constant Conditions

No. 3 Vertical Stationary Digester

Liquor ratio, ml/g o.d.	3.5
Active alkali, as Na_2O, %	16
Sulfidity, %	25
Maximum temperature, °C	172
Time to max. temp., min	60

Sample A is debarked pine wood chips
Sample B is whole tree wood chips

earlier for lignin and nonlignin material entering the digester in Cooks 4 and 5, it is found that, after cooking, 78.5% of the lignin in the debarked wood was removed along with 32.8% of the nonlignins. The same calculation for the whole tree chips shows that only 72.4% of the wood lignin present was removed, along with 45.7% of the nonlignins. Since the single variable not identical in the two cooks is the composition of the raw material, the difference in degree of delignification must be assessed to the presence of the nonwood constituents.

The single-pass refining step, accomplished in a 12-inch Sprout Waldron disk mill, was designed to produce a high-yield kraft fiber from the laboratory-produced softened chips having most of the characteristics of the refined mill pulp. The plates were heated and sufficient hot water was introduced with the hot chips to produce a pulp slurry of about 5% consistency. Inspection of handsheets made from the unbeaten, refined commercial pulp and from the disk-milled laboratory-produced pulp showed little difference in appearance. Fiber classification data (Table I) indicate that the laboratory fiberizing was probably much milder than that achieved in the mill. Freenesses were quite similar.

Representative samples of the pulps from Cooks 4 and 5, and the refined commercial pulp were tested for extractives, depositable pitch, ash content, and calcium and silica content of the ash. The data are given in Table IV. No outstanding differences between the two laboratory-prepared pulps came to light. Although the whole tree pulp was slightly higher in both total alcohol-benzene extractives and depositable pitch than the pine chip pulp, the differences are not considered significant. Both were much lower in extractives than the mill pulp sample. The increased entrainment of field dirt expected in the whole tree harvesting process was monitored by measuring the ash contents of the pulps and checking these for calcium and silica. Although a greater ash and silica content was found for the whole tree pulp than for the debarked wood pulp, neither approached the levels found in the commercial pulp. The greater ash content of the commercial pulp could very well be related to the degree of washing achieved — much more efficient in the laboratory than in the mill. It is possible that this also accounts for the higher extractives content of the mill pulp but the explanation has no experimental support. The two experimental pulps were very similar in calcium content, and both were higher in this element than the commercial pulp. The significant point here is that the two laboratory-prepared pulps are not different. The fact that extractives from both are higher in calcium than the commercial pulp is probably indicative of harder water in this locality than in that of the mill.

TABLE IV

CHEMICAL PROPERTIES OF PINE KRAFT PULPS

Pulp	Cook 4	Cook 5	Commercial
Wood source	Whole tree	Debarked pine	Debarked pine
Extractives, %	0.22	0.18	1.36
Depositable pitch, mg	7.3	6.2	6.8
Ash, %	1.51	1.37	3.46
Calcium, %	0.30	0.362	0.095
Silicon dioxide (SiO_2)	4.8	2.0	5.2

Evaluation of the physical properties of the pulps was undertaken directly in spite of the disparity in lignin content. The standard beater run as outlined in Methods T 200 ts-66 and T 205 m-58 was modified to permit extraction of larger samples at each beating interval and preparation of more than the usual number of handsheets. The data obtained are shown in Table V. A relatively large number of physical properties was measured. Some of these are plotted against beating time in Fig. 1 and 2. Figures 3 and 4 use the same relationships to give a direct comparison of some of the more basic sheet properties. It may be noted, from these comparisons, that the whole tree pulp develops tensile and bursting strength at about the same rate as the debarked pine pulp in the early part of the beating cycle, but that it does not sustain the same rate on further beating. The beating rate (Fig. 3) as measured by freeness drop, is greatest for the whole tree pulp but, as with burst and tensile strength, does not show much difference during early beating. The tear factor favors the conventional pulp by quite a large margin, however, at all beating levels. Folding endurance was appreciably better over most of the beating cycle for the debarked pine pulp. Stiffness and edgewise compression tests likewise favor the conventional pulp. Only in tensile energy absorption (TEA) is there any advantage favoring the whole tree pulp. This property was not included in either graph.

A relatively simple and convenient way of comparing pulp strength potential is to examine the effect upon tearing strength as the tensile strength is improved by beating. Figure 5 compares the refined commercial pulp, and the pulps from Cook 4 (whole tree chips) and Cook 5 (debarked pine chips). The tearing strength of both of the laboratory prepared pulps is shown to exceed that of the commercial pulp over the whole beating range. This may be related

E R R A T U M

Page 12, Lines 17 and 18

Please change to read:

The stiffness test likewise favors the conventional pulp.

TABLE V

PHYSICAL PROPERTIES OF EXPERIMENTAL PULP HANDSHEETS

Pulp[a]	4	5	4	5	4	5	4	5	4	5
Beating interval, min	0		5		15		30		50	
C.S. freeness, ml	760	765	740	765	725	755	695	735	610	655
Density, g/cc	0.411	0.403	0.428	0.432	0.464	0.496	0.493	0.522	0.541	0.570
Burst factor	28.5	26.5	35.0	32.8	42.0	47.5	49.6	58.0	58.5	67.0
Tear factor	209	292	194	265	185	220	166	190	146	171
Tensile — br. l., km	4.5	4.87	5.73	5.77	6.31	6.97	7.46	8.24	8.52	9.23
Stretch, %	2.2	1.6	2.3	1.9	2.3	2.1	2.6	2.3	2.8	2.6
TEA, kg m/m^2	4.01	3.01	5.17	4.37	5.76	5.47	7.88	7.32	9.42	9.30
Exten. stiffness, kg/cm	305	358	322	407	373	420	397	472	450	487
Edge compr. lb/inch	5.3	4.7	5.2	5.1	5.6	5.4	6.0	5.4	6.1	6.0
Porosity, ml/min	3370+	4.7	3370+	5.1	3370+	5.4	3370+	5.4	1390	1480
Sc. coeff. cm^2/g	209	202	193	191	185	176	173	160	154	148
Fold (MIT)	149	203	305	497	408	787	650	897	956	877

[a]4. Whole tree.
5. Debarked pine chips.

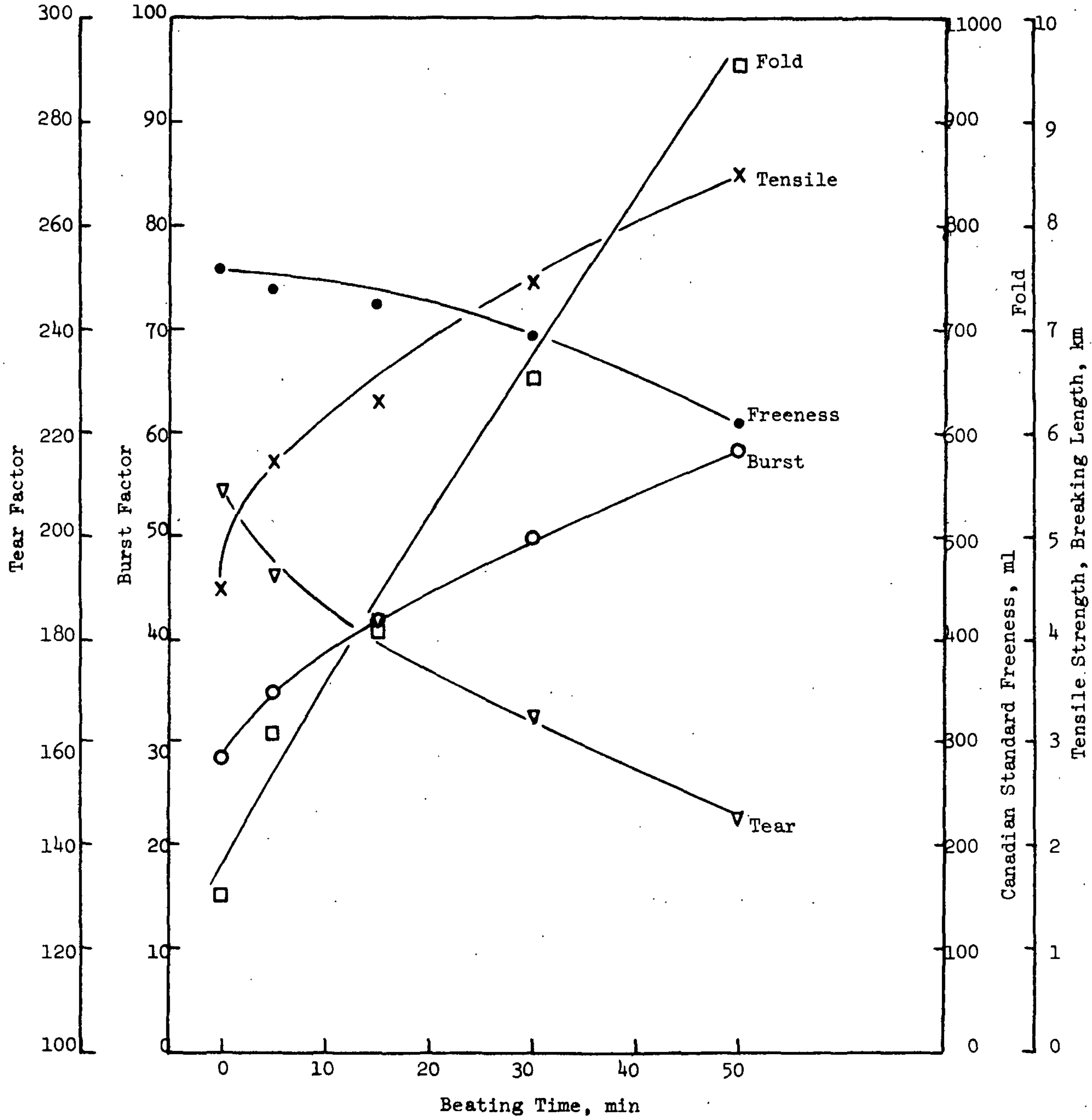


Figure 1. Physical Properties of the Pulp of Cook 4 (Whole Tree Pulp)

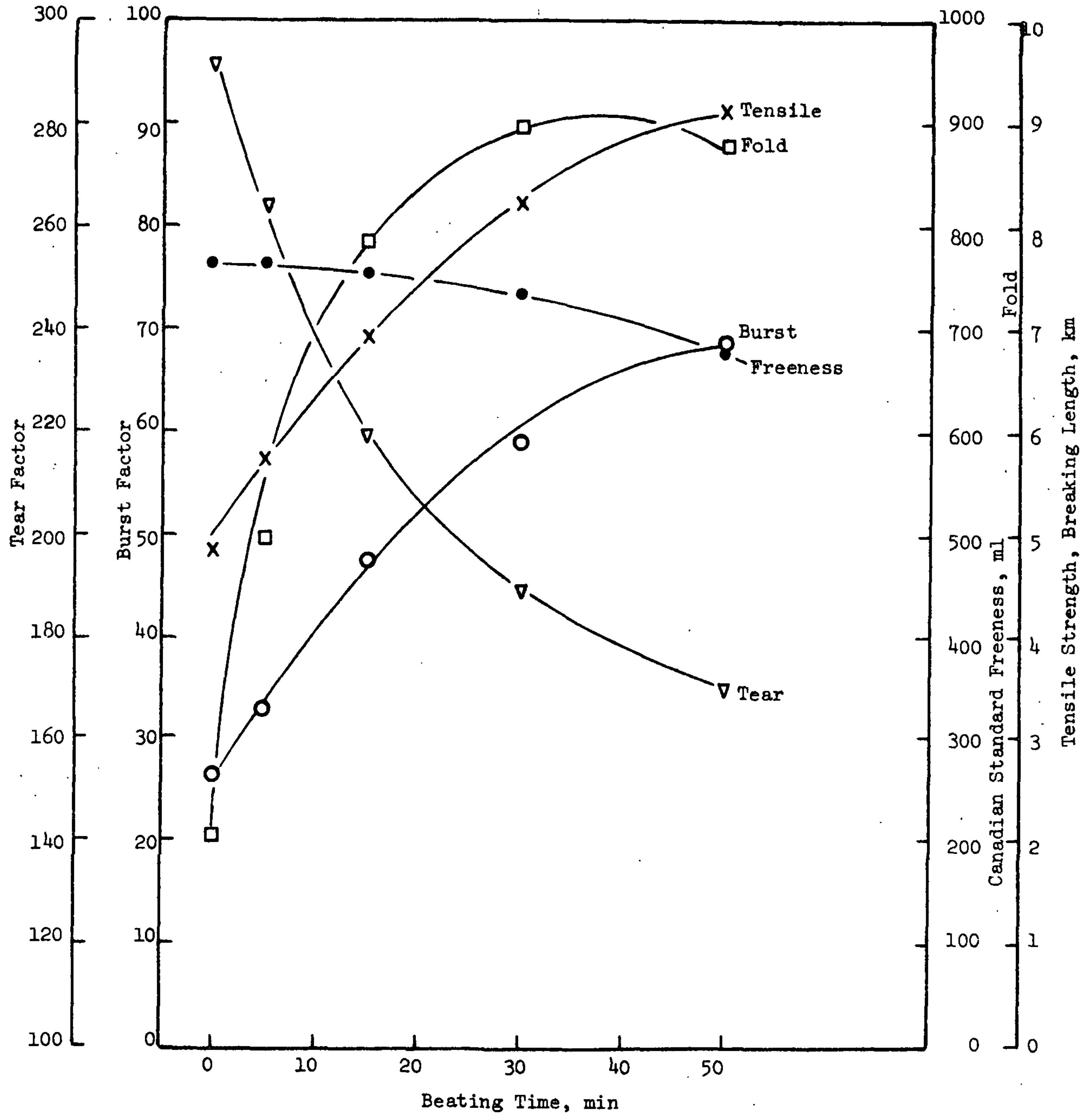


Figure 2. Physical Properties of the Pulp of Cook 5 (Debarked Pine Pulp)

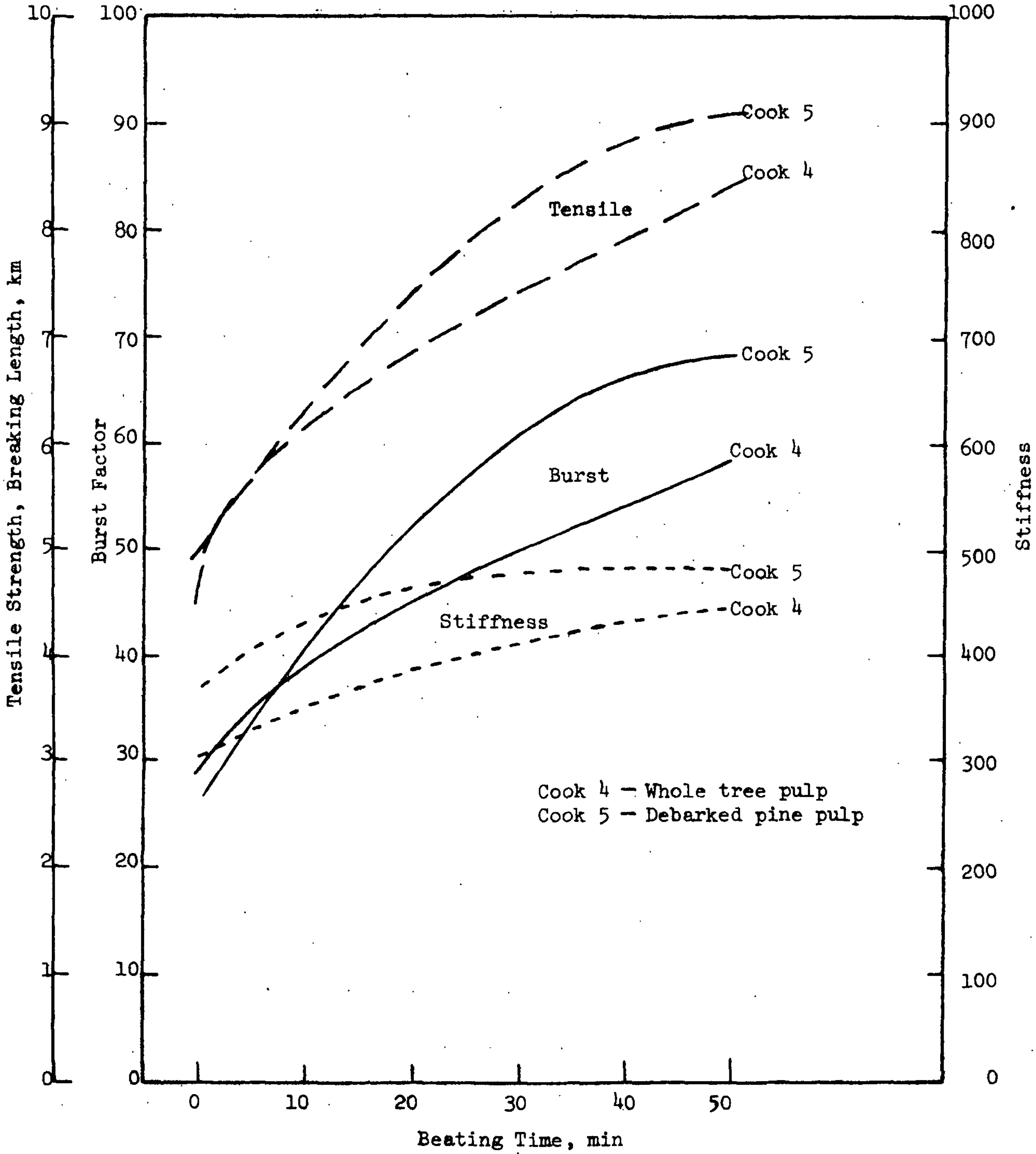


Figure 3. Comparison of Properties of Pulps From Cooks 4 and 5

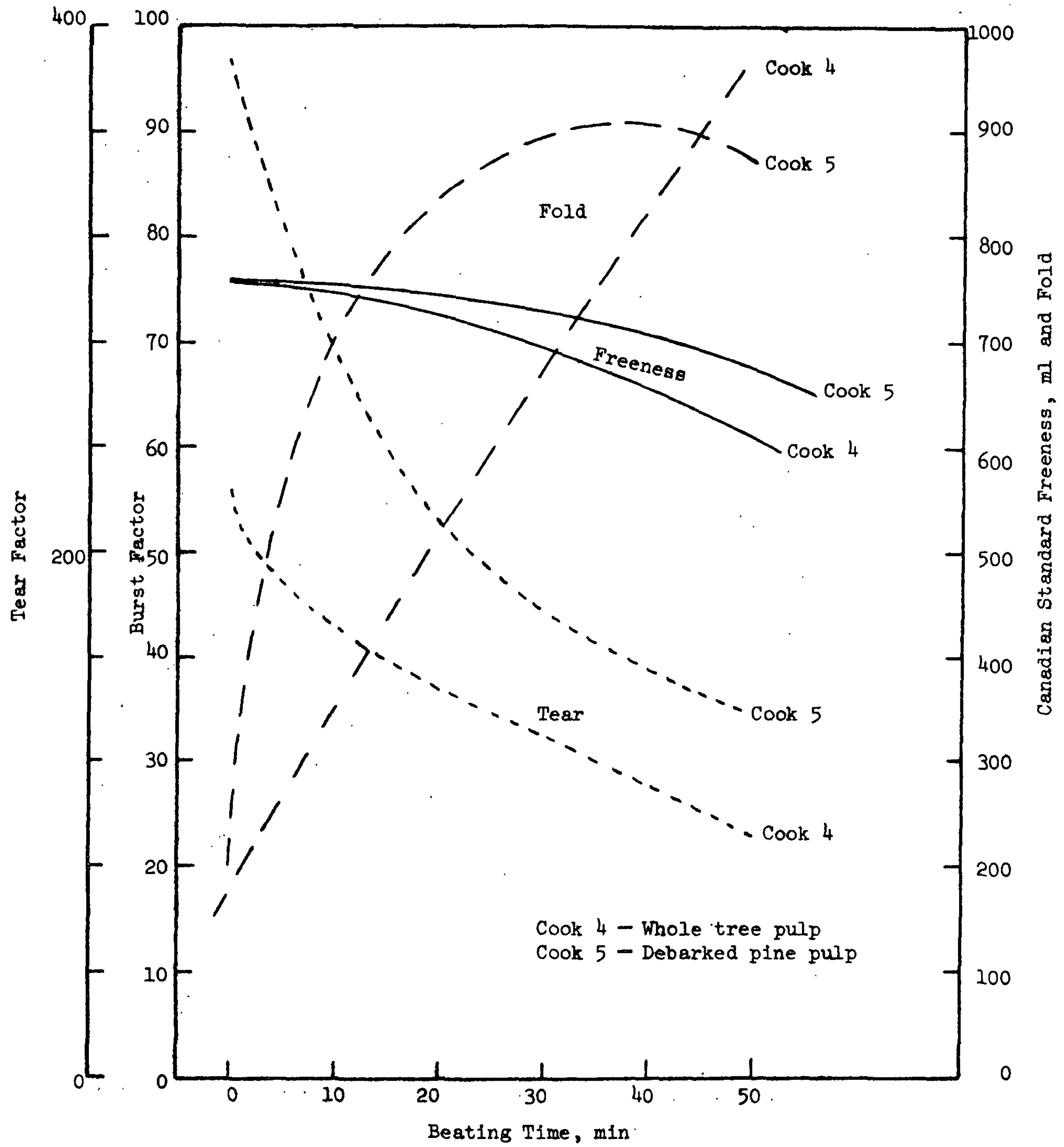


Figure 4. Comparison of Properties of Pulps from Cooks 4 and 5

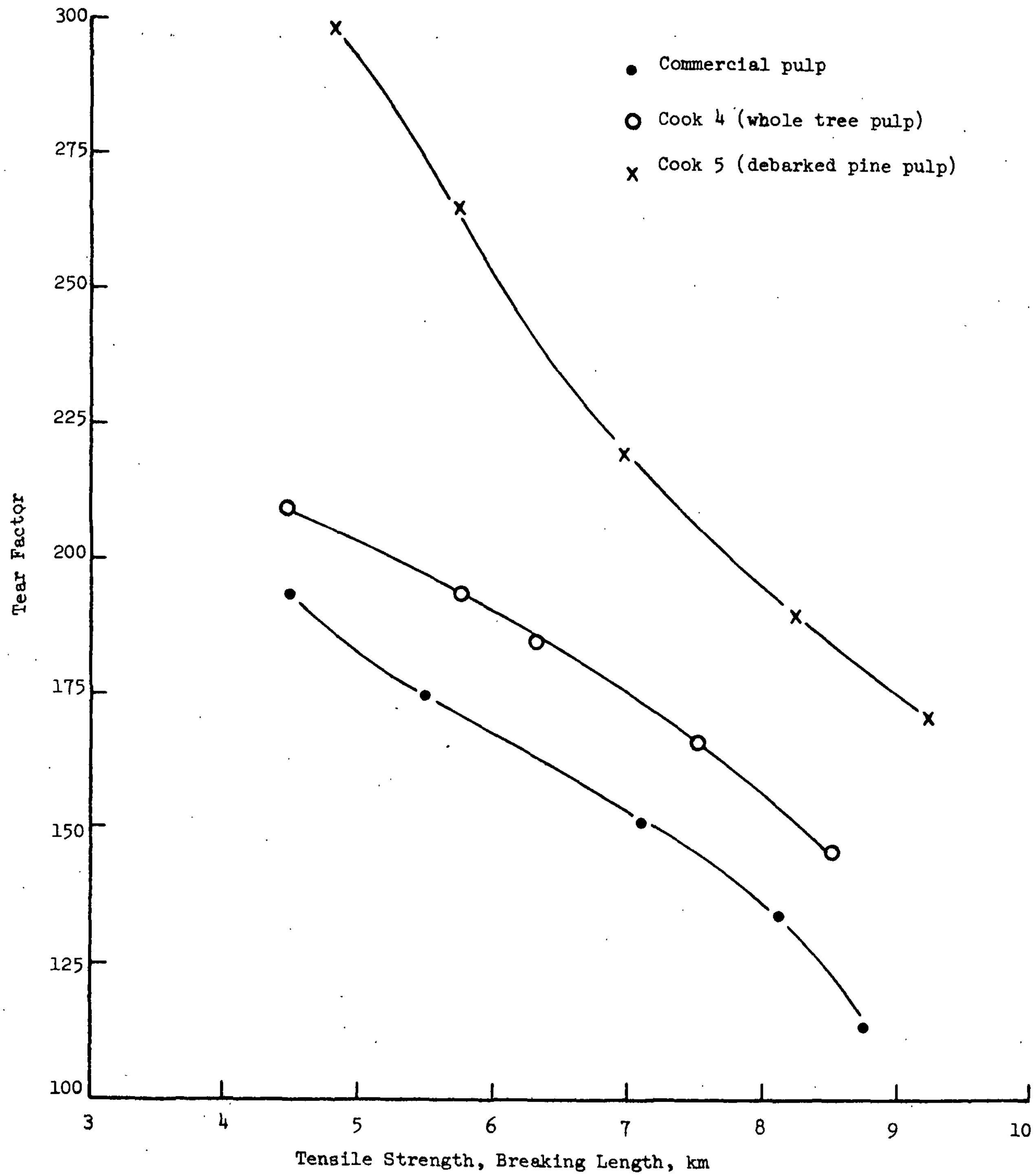


Figure 5. Tearing Strength at Several Levels of Tensile Strength

to greater control of digester variables in the laboratory or to less fiber damage during primary refining, or to both. The considerably greater tearing strength of the pulp from debarked wood as compared with whole tree pulp probably would not be as great if both were cooked to the same level of Kappa number (lignin content). On the other hand, the burst and tensile strengths of the whole tree pulps would probably be less at a higher tear resistance.

Inasmuch as high-yield, unbleached kraft pulps are used in board grades having a basis weight higher than the 60 g/m^2 used in the standard beater evaluation, two board weights (42-lb and 26-lb/1000 ft^2) were used in measuring the effect of including some of the whole tree pulp with pulp from debarked pine. The combination of 60 Kappa number debarked pine pulp and 76 Kappa number whole tree pulp was rationalized by assuming, from existing data, that the inclusion of whole tree chips with conventional chips would result in increases in Kappa number and decreases in yield. Basically, the same thing could be considered to have happened when the two pulps were blended.

The degree of beating chosen for the pulp mixtures was based on a recommendation from the cooperator (letter Carlson to McKee dated Dec. 5, 1973) that the burst factor be in the 30-35 range and that the freeness be in excess of 710. Reference to Table V shows that both pulps attained these values after 5 minutes of beating. As might be expected, handsheet formation with such lightly beaten stock proved to be difficult. Sheets tended to adhere both to the wire mesh surface of the sheet mold and to the blotters after pressing. Larger than usual numbers of sheets were made to permit selection of the best ones for testing. The drainage rate (time to drain a sheet in the sheet mold) was measured but was so rapid that little difference was noted that could be attributed to the variation in the whole tree pulp content. Freeness values of lightly beaten pulps were of little practical value, though the mixture of equal amounts of the pulps of Cooks 4 and 5 were probably just a bit lower in freeness than 100% Cook 5 pulp.

Examination of the data for the liner weight handsheets showed a degree of variability that could be reconciled only with the difficulty encountered in making good handsheets. Trends were difficult to recognize and the scatter of the data reduced confidence limits in their validity. Authorization to repeat the work at a higher refining level was obtained. Both pulps were beaten for 12 minutes and 200 cm^2 handsheets were made following the general method outlined in T 205 m-58. The physical properties of the sheets are given in Table VI. It will be noted that even after 12 minutes beating to a burst factor in excess of 40, the freeness is ca. 750 ml CS and changed little with the changing composition of the mixtures. Handsheet drainage times were too short to provide any evidence of differences attributable to the use of whole tree pulp. Of the physical properties measured, only tear factor seemed to suffer from the addition of the whole tree pulp.

In none of the testing was there any positive evidence of greater "stickiness" or foaming tendencies in the whole tree pulp. This would be in agreement with the analytical data showing the similarity in pitch and extractives. However, there were some indications of differences that were purely subjective. Technicians complained of difficulties in dewatering the whole tree pulp on filter paper because of almost instant blinding of the pores by a fine, gummy material. When the handsheets from mixtures were made from lightly beaten pulps, the tendency to adhere to the sheet mold wire and couch

TABLE VI

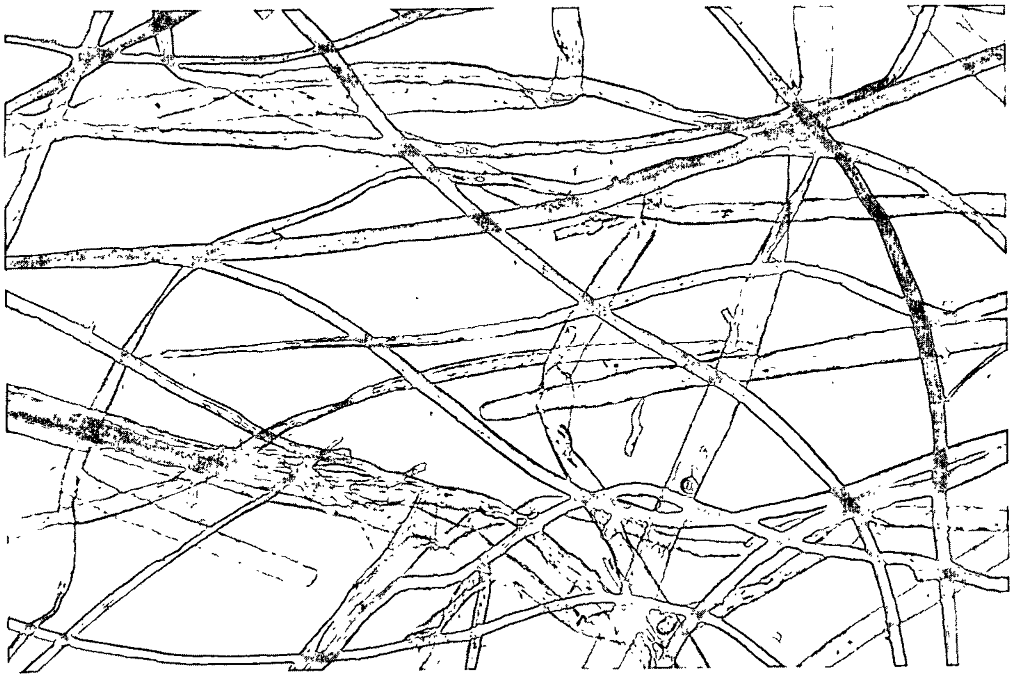
COMPARISON OF PHYSICAL PROPERTIES OF
LINERBOARD WEIGHT HANDSHEETS

	Nominal 42 lb/1000 ft^2					Nominal 26 lb/1000 ft^2				
Debarked pine pulp, Cook 5, %	100	90	80	70	50	100	90	80	70	50
Whole tree pulp, Cook 4, %	0	10	20	30	50	0	10	20	30	50
Canadian standard freeness, ml	755	760	735	740	755	755	760	735	740	755
Drainage time, sec., at	--	4.8	4.8	4.9	4.8	--	--	--	--	--
Temperature, °C	--	19	18.5	18.5	18.4	--	--	--	--	--
Basis weight, lb/1000 ft^2	42.2	45.0	40.4	43.1	40.2	26.7	25.9	29.2	27.2	25.9
Caliper, μm	364	406	366	372	354	241	234	269	251	238
Density, g/cc	0.566	0.542	0.538	0.565	0.554	0.544	0.538	0.532	0.530	0.529
Burst factor	41.3	40.8	41.5	41.6	41.7	42.5	40.0	41.4	44.3	41.8
Tear factor	241	253	228	227	216	198	208	206	192	182
Tensile, lb/inch	102	108	96.2	106	98.1	45.2	44.6	48.1	45.0	44.0
Tensile, lb/inch	102[a]	101[a]	100[a]	103[a]	102[a]	44.0[b]	44.8[b]	42.8[b]	43.0[b]	44.2[b]
Stretch, %	2.6	2.2	2.2	2.3	2.4	2.1	2.0	2.2	2.2	2.3
Porosity, ml/min	2110	2050	2030	1840	1970	2994+	2946+	2598	2574	2736
Edgewise compression, lb/inch	17.9	19.3	17.4	19.0	17.8	12.6	11.6	12.9	13.1	11.8

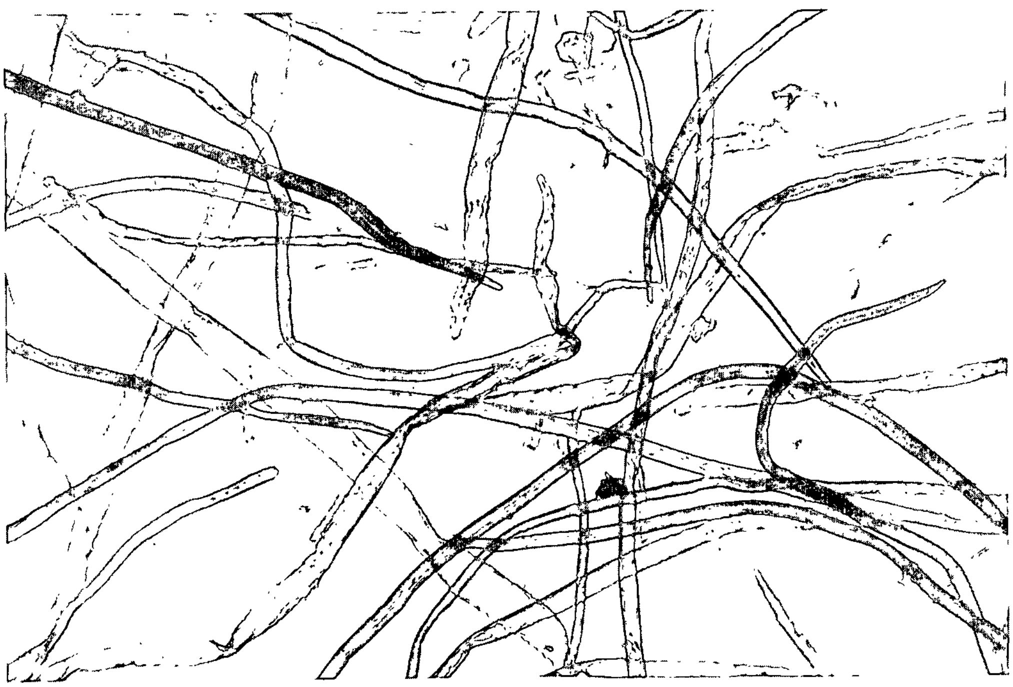
[a]Adjusted to 42.0-lb basis weight.
[b]Adjusted to 26.0-lb basis weight.

blotter seemed to increase with increased use of the whole tree pulp. It should be pointed out that analytical data are well known to be poorly correlated with the formation of "troublesome pitch" in mill systems. It is especially dangerous to make sweeping generalizations on the subject on the basis of a very few tests such as those described above.

The photomicrographs made on samples of washed, unbeaten pulps representative of the mill products, Cook 4 (whole tree) and Cook 5 (debarked pine) are shown in Fig. 6. They appear to be very similar except for the presence of a small amount (ca. 5%) of hardwood fibers in the mill pulp and more cell wall debris and thin-walled sieve cells from the secondary phloem in the pulp of Cook 4 (whole tree).



A. Cook 5, Debarked Pine Chips



B. Cook 4, Whole Tree Pulp

Figure 6. Photomicrographs of Mill and Experimental Pulps

C. Mill Pulp

Figure 6 (Continued). Photomicrographs of Mill and Experimental Pulp

CONCLUSIONS

The data generated by this investigation of the quality of high-yield kraft pulp made from whole tree chips permit the following conclusions:

1. The nonwood portion of the whole tree chip supply furnished for this project made up about 10% of the weight. The action of the chipper was sufficient to break the bark free from most of the wood, as witness, the small (4.5%) fraction of wood plus bark in the manual separation of components of the whole tree chip sample.
2. The relatively small nonwood fraction of the whole tree chips had a substantial effect on the kraft pulping process used in the experimental digestions. Alkali, essential to the delignification of the wood, was obviously dissipated in reaction with the extraneous material more prevalent in the whole tree chips. It was calculated (using data from Table III) that a pulp made in the laboratory from debarked pine chips would have a yield of about 56.5% if pulped to Kappa number 76 as compared to the 47.5% yield obtained in Cook 4.
3. If it is assumed that, under normal circumstances, only a portion of the wood going to the digester would be whole tree chips, then the net result of their inclusion, as indicated by the cooking data, would be to either (a) require a larger chemical charge to satisfy the demand created by presence of the extraneous materials, or (b) adjustment of other variables to permit the depleted chemicals to perform the required amount of delignification.

4. Using the same assumption as in (3) it would appear that, at the same degree of delignification, a loss in yield nearly the equivalent of the nonwood chip portion of the raw material entering the digester could be expected.

5. If no corrective adjustments were made, the net effect of including whole tree chips as a part of the raw material going into the pulp mill would be a drop in yield and an increase in pulp lignin content.

6. If the whole tree chips are blended with conventional chips and adjustments are made to bring the product to about the same Kappa number as attained in pulping debarked wood, little change in bursting and tensile strength would be expected in the linerboard product up to 50% whole tree pulp. A drop in tearing strength would probably be detected only after quite heavy dilution of the debarked wood chip furnish.

7. If whole tree chips are blended with debarked pine chips, and no adjustments in cooking conditions are made, the board made from the pulp would probably not be materially lower in tensile or bursting strength than board made with 100% debarked pine chips but would have distinctly lower tear factors.

8. No convincing evidence of higher than normal pitch or "troublesome" pitch was discovered in the pulp made from whole tree chips. Extractives and depositable pitch were minimally increased and some stickiness was observed during pulp handling but the differences were not enough to cause concern at this time. As pointed out earlier, the tests applied are not well correlated

with the presence of "troublesome" pitch, and the amount of data collected is too small to permit the formation of a definite opinion in the matter.

9. If the cooking conditions are changed to produce pulp of equivalent lignin content, it is felt that the inclusion of whole tree chips along with debarked wood chips would not materially change the appearance of the linerboard made from the pulp.

10. It would appear logical to assume greater entrainment of dirt in whole tree chips than in chips from wood bolts passed through a barking drum. This was apparently supported by the greater SiO_2 content shown in Table IV. The fact that the commercial pulp has an even higher silica and ash content than the whole tree laboratory-prepared pulp may relate to the difference in pulp washing as performed in the laboratory and the mill (more efficient in the laboratory).

11. The presence of up to 50% whole tree chips in a kraft pulping-papermaking operation was simulated by testing board weight handsheets made of mixtures of pulps. At the beating level chosen (to about 40 burst factor) it could not be demonstrated that board quality would suffer appreciably due to the inclusion of the whole tree chips. Bursting and tensile strengths were as good at 50% whole tree pulps as for debarked wood pulp alone. Tear factor was off 8-10% with the 50% addition.

EXPERIMENTAL

Two 55-gal drums of wood chips were received at the Institute; one contained pine chips obtained from the Roanoke Rapids, North Carolina mill of the Hoerner Waldorf Corporation and one contained whole tree chips from the same source. Each batch was handled separately but in an identical manner. After thorough mixing, the chips were divided into 9.0-kg digester charges which were packaged in polyethylene bags. Representative samples were taken, weighed, ovendried to constant weight and discarded. The pine chip packages were found to contain 4.392 kg moisture-free wood, the whole tree chips 4.578 kg on the same basis.

A representative sample of the whole tree chips was separated manually into four components, viz. (1) wood chips entirely free of bark, (2) wood chips with firmly adhering bark, (3) bark fragments, and (4) leaves and needles.

In a separate shipment, three pulp samples were presented. One, from the C Washer of the Hoerner Waldorf mill at Roanoke Rapids, was found to have a moisture-free consistency of 15.77%. The pulp sample taken following the refiner had a consistency of 18.42% o.d. The headbox stock contained 3.9% moisture-free solids. (These values are as determined in the laboratory. Dewatering prior to shipment is not discounted, since the originating mill reports 3-4% consistency after the refiner and 0.4% for headbox stock.) Besides consistency measurements, a single determination test of the Kappa number of the refined stock was carried out, using the Hoerner Waldorf 5-min routine test method, as submitted by Hoerner Waldorf's John Gladstone. Bauer McNett Classifications (TAPPI Method T 233 su-64) were carried out on all three samples. The refiner stock, which had an initial freeness of 750 ml Canadian Standard, was beaten to 330 ml CSF in 50 min. Handsheet data and freeness values at five beating times (including zero beating) were obtained.

The pine chips were pulped as described by Mr. Gladstone in a letter dated September 11, 1973. This is Cook 1 in Table III. The digester used is a vertical cylinder of stainless steel construction described in detail by Thode, et al. (4). . It is equipped to provide liquor circulation and external heating in a steam heat exchanger. The chips were charged to a stainless steel liner having a conical, perforated bottom which matches the contours of the lower part of the digester. At the end of the scheduled cooking time, the spent liquor was discharged through the blow valve into a muslin-covered box from which any entrained fiber was later salvaged and included in the determination of pulp yield. The hot chips were weighed and a representative portion was segregated for the yield test. The remainder was transferred to a 12-inch single disk Sprout Waldron refiner fitted with No. 17,804 plates set at 0.018-inch clearance. A belt conveyor feed delivered the hot, cooked chips to the steam-heated refiner at a uniform rate. Hot water was metered into the disks at a rate designed to deliver fiberized pulp at ca. 5% consistency. This was washed in a tank having a perforated false bottom. Effluent after each of the three wash cycles (10 min, 5 min, and 5 min at full dilution in the 60-gal tank stirred with a Unipower stirrer) was directed to a muslin-covered box from which it drained to the sewer. Entrained fiber was returned to the tank. After washing, the pulp was dewatered in a closely woven nylon bag placed in a laundry centrifuge. The pulp cake was broken up and stored in polyethylene bags in a room maintained at 5°C. The sample removed for yield testing was fiberized under a Williams stirrer and washed on a muslin-covered box. The washed pulp was first dewatered on a coarse filter paper in a table Buchner, then the pulp cake was oven dried *en toto*. Yield data were obtained by the formula $\frac{\underline{B}}{\underline{A}}$,

where $\underline{A}$ = moisture-free weight of the wood and $\underline{B}$ is obtained by

the calculations of $\dfrac{\underline{E} \times 100}{\frac{\underline{D}}{\underline{C}}} = \underline{B}$

$\underline{C}$ = weight of drained, cooked chips

$\underline{D}$ = weight of representative sample of drained, cooked chips

$\underline{E}$ = ovendry weight of fiberized and washed sample $\underline{D}$.

Hoerner Waldorf 5-min Kappa number of 82.8 and a yield of 61.5% indicated considerable undercooking so Cook 2 was made with a 50% increase in time at maximum temperature. The Kappa number dropped to 67.2 and the yield to 52.6%. A plot of Kappa number *vs.* time at maximum temperature indicated that the target Kappa number of 60 should be attained by cooking for 68 minutes at maximum temperature. Cook 3, made in this manner, actually had a Kappa number of 55.7. An adjustment in the line of best fit, using this number in the plot of Kappa number *vs.* time at maximum temperature showed that 65 min at temperature should produce a Kappa number of 60. Cook 4 on the whole tree chips and Cook 5 on the pine chips were made in this manner. The pine chip pulp had a Kappa number of 60.5 and a yield of 51.66%. The whole tree pulp had a Kappa number of 76.0 and a yield of 47.5%.

The pulps were tested in the manner described for the commercial pulp with the exception that larger amounts of stock were taken from the beater and more handsheets made for a greater number of tests. The liner weight sheets were made on the same mold (described in T 205 m-58) using the forming, pressing and drying procedures listed there. Enough pulp was beaten and stored to provide all of the freeness data and handsheet material. Certain properties were ascertained by analytical procedures, e.g., ash, SiO_2 in the ash, ethanol-benzene extraction of the two laboratory-prepared pulps and the cooperator's refined pulp and amounts of calcium present in the same three pulps. The three pulps were also tested for depositable pitch by the canister method. Photomicrographs were made at 75X magnification for visual comparison of the several pulps.

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John R. Peckham

John R. Peckham
Research Fellow
Division of Materials
Engineering & Processes

R C McKee

R. C. McKee
Chairman
Container Section